Using satellite imagery for African bird conservation

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L'utilisation de l'imagerie satellitaire pour la conservation des oiseaux en Afrique. L'imagerie satellitaire est utilisée de plus en plus par la science de la conservation des oiseaux. Les images peuvent couvrir de vastes zones de façon de plus en plus détaillée et fréquente, ce qui en fait un outil formidable, et une alternative aux inventaires coûteux sur le terrain. Elles sont également disponibles pour des régions ou pays politiquement instables, éloignés ou inaccessibles, ce qui les rend particulièrement utiles pour des zones impossibles à inventorier sur le terrain. En plus de l'identification de sites d'importance pour la conservation auparavant inconnus, ces données ont été utilisées pour comprendre la distribution de certaines espèces et d'en dresser la carte, et pour découvrir les changements dans la couverture végétale (ce qui peut être utilisé comme une indication pour la perte d'habitat) pratiquement en temps réel. Bien que l'imagerie satellitaire ne constitue pas une panacée, et ne remplacera jamais les données obtenues sur le terrain, le ciblage approprié de la technologie pourrait fournir une contribution importante à la conservation des oiseaux en Afrique.

Summary. Satellite images are increasingly used in avian conservation science. Images can cover extensive areas in increasing detail at increasing frequencies, making them a great tool, and an alternative to expensive field surveys. They are also available from regions or countries that may be politically unstable, remote or inaccessible, making them especially relevant for areas that cannot be covered by field surveys. In addition to identifying previously unknown sites of potential conservation importance, these data have been used to understand and map species distributions, and track changes in land cover (which can be used as an indication of habitat loss) in near real time. While satellite images are not a panacea, and will never replace the need for field data, appropriate targeting of the technology could make a substantial contribution to avian conservation in Africa.

Many will be familiar with satellite images and aerial photographs of the Earth through the advent of websites such as Google Earth (http://earth.google.com). Visual examination of these images has already resulted in the discovery of sites of potential conservation importance and is being used to target field surveys at interesting areas (e.g. Dowsett-Lemaire 2010). Other sites of conservation importance may come to light through the simple process of examining these images for areas of potentially interesting habitats in otherwise degraded landscapes. However, this is just one of many ways that the information collected by satellites can be used to support bird conservation in Africa, and indeed globally. Here, we outline some of the means by which satellite imagery can help conservationists and researchers, and describe some initiatives that might pave the way for a new generation of bird monitoring and research in Africa.

Satellite images

Satellite images are taken by space-borne sensors that measure at-sensor variation in radiation reflected or emitted from the Earth's surface; essentially, they take photographs from space, though unlike ordinary cameras, they also collect information from wavelengths above and below those visible to the human eye. The radiation they capture can be that which is reflected from the Earth's surface from natural sources (passive sensors), such as sunlight, or that reflected from an artificial radar source mounted on the satellite itself (active sensors). The characteristics of the surface of the Earth cause variation in the reflectance measured by the sensors. For example, forest absorbs different wavelengths of light from grassland, so there are differences in the reflected light picked up by satellites from these formations (Fig. 1). Satellite images can therefore be used to make objective assessments of land cover across areas that are too extensive to survey on the ground, too inaccessible or too politically unstable. Some very high-resolution sensors (e.g. Quickbird) collect information at the scale of 1 m^2, while other sensors (e.g. SPOT—Vegetation) possess resolutions of nearer 1 km^2. But there is a trade-off between this spatial resolution and the number of times each satellite passes over the same location (the temporal resolution). The SPOT and

MODIS sensors are housed on satellites that pass over each part of the Earth's surface daily, whereas the 'revisit' times of other sensors are longer (e.g. 14 days for the 28-m^2 resolution Landsat sensors).

The ability to collect information on land cover anywhere in the world, and to access that information from anywhere in the world, clearly makes satellite imagery a powerful tool in the resource-limited field of conservation. However, some ground-based work is normally required to collect data against which image interpretations are subsequently made, or to verify these interpretations. Further, clouds obscure the land surface from passive sensors, meaning these sensors may not be appropriate for monitoring very cloudy areas, especially during the wet season.

Applications for conservation

Studying birds

The number of avian studies that have used remote sensing has increased in recent years (Gottschalk *et al.* 2005). While the majority of papers that have used remote sensing to study the abundance, distribution or diversity of birds have focused on North American or European species, Africa has been the next most frequently represented continent (Fig. 2).

Satellite sensors cannot yet detect individual birds (though satellites have been used directly to monitor large aggregations of birds: Guinet *et al.* 1995). However, the data they collect can be used to estimate the potential distributions of species, which can in turn be used to plan

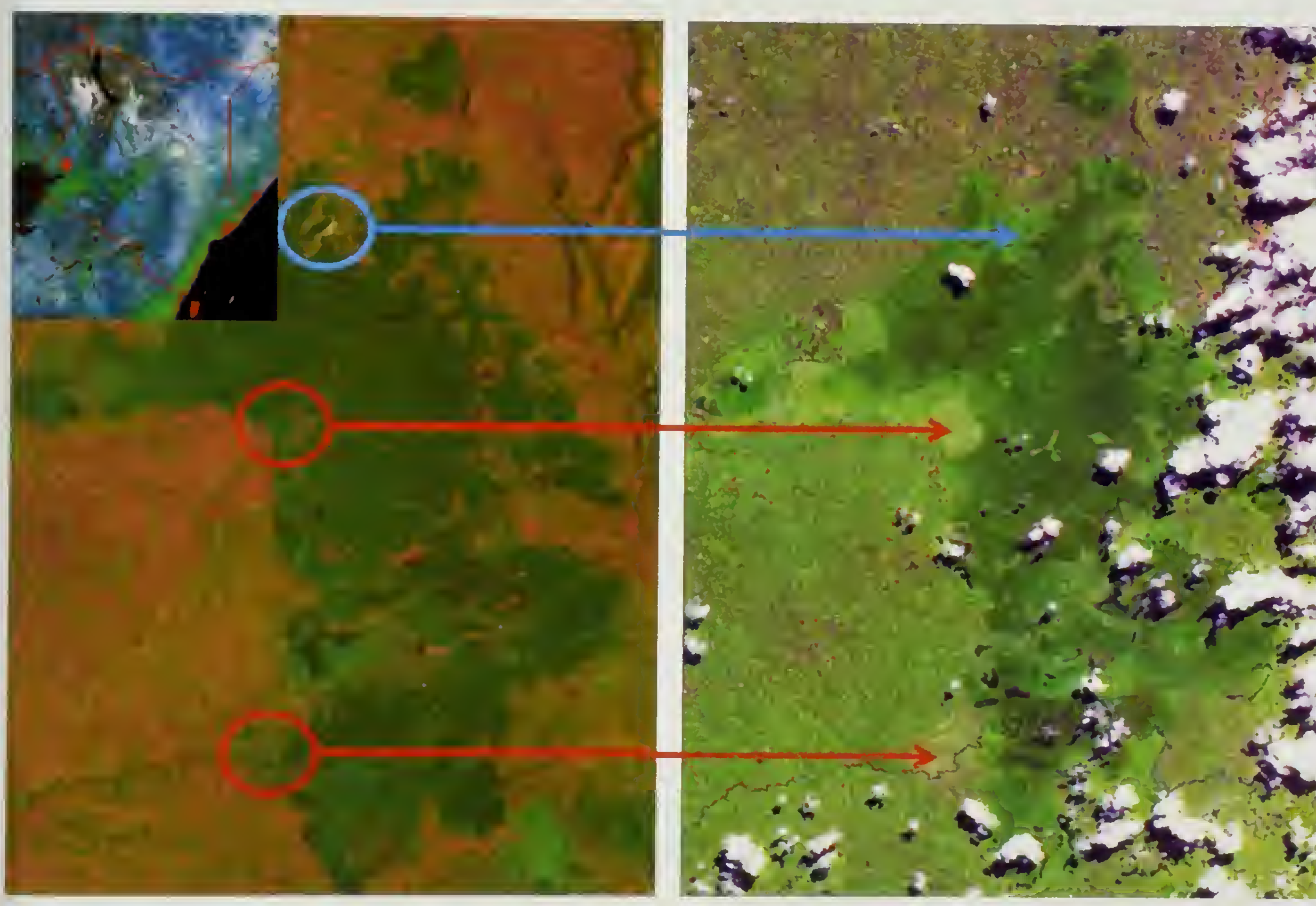

Figure 1. Example of satellite image of Kakamega Forest in western Kenya (inset) in 1975 (left) and 2006 (right). In this combination of bands, dense forest is shown as dark green, open forest, dense shrub or plantations are pale green. Herbaceous formations and agriculture show as pink. Red arrows indicate example areas of forest loss, while the blue arrow indicates forest re-growth. The irregular white objects are clouds, which are often a limiting factor in analysis of passive satellite images.

Un exemple d'une image satellitaire de la forêt de Kakamega à l'ouest du Kenya (en médaillon), en 1975 (à gauche) et en 2006 (à droite). Cette combinaison de bandes montre la forêt dense en vert foncé et la forêt ouverte, les broussailles et les plantations en vert clair. Les formations herbacées et les zones cultivées sont en rose. Les flèches rouges indiquent des zones où la forêt a été détruite, tandis que la flèche bleue indique une zone où la forêt est en train de se régénérer. Les objets blancs irréguliers sont des nuages, qui constituent souvent un facteur limitatif pour l'analyse des images satellitaires passives.

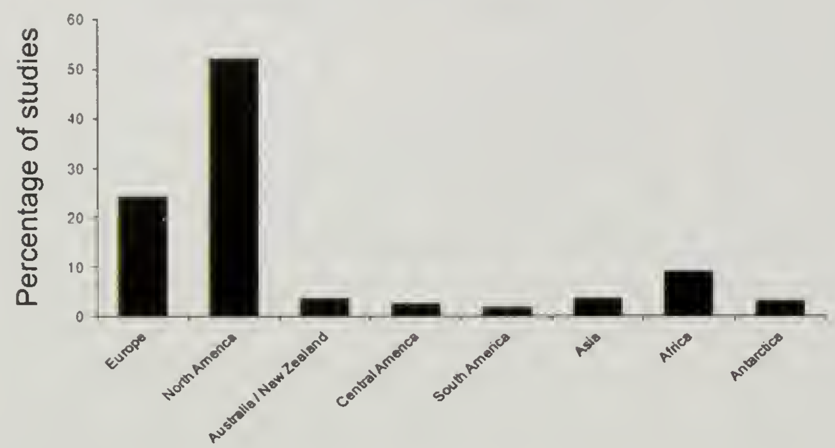

Figure 2. Geographical distribution of published studies (from first in 1982, up to 2007) of bird abundance, distribution or diversity that have used remote sensing data, based on literature searches using keywords (remote sensing, bird, avian, satellite, image).

Distribution géographique d'études publiées sur l'abondance, la distribution ou la diversité aviaires (de la première en 1982 jusqu'en 2007) qui ont utilisé des données obtenues par télédétection, basée sur des recherches de la littérature en utilisant des mots clés (télédétection, oiseau, aviaire, satellite, image).

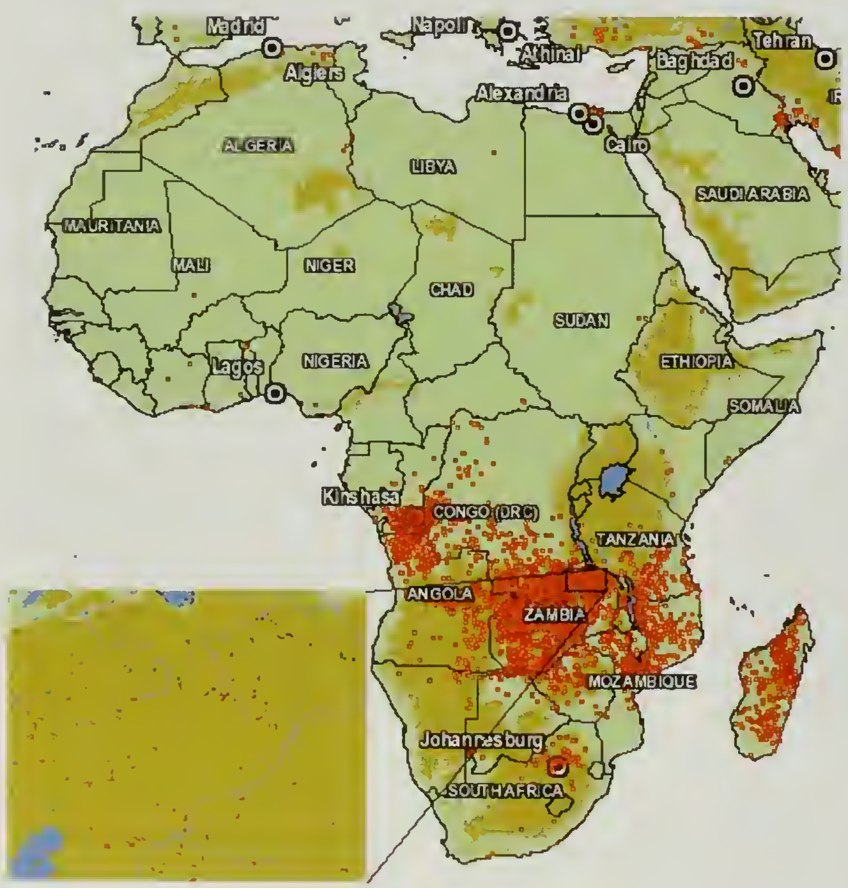

Figure 3. Active fires in Africa on 22 September 2009, including finer detail in north-east Zambia (inset). Data from http://firefly.geog.umd.edu /firemap

Feux en Afrique, le 22 septembre 2009; en médaillon le nord-est de la Zambie. Source : http://firefly.geog.umd.edu /firemap

conservation strategies or priorities. The simplest method is to use known habitat associations of species and categorical land-cover maps (produced from data collected by satellites) and other data (e.g. satellite-derived maps of topography, also now commonly available) to estimate the extent of potentially suitable habitats. These can be based on specifically produced land-cover maps, or readily available pre-processed land-cover maps such as GLC2000 (Mayaux *et al.* 2004) or Africover (www.africover.org). The wide availability of GPS technology now means that bird sightings can be overlaid on satellite images with a high degree of accuracy. Consequently, it is possible to describe apparent habitat associations of species from land-cover maps (Fuller *et al.* 2005).

Bird distributions, or more correctly the suitability of land cover (habitat) for birds, can also be mapped without categorical land-cover maps, by linking bird data directly to satellite image data (in particular, the Normalised Difference Vegetation Index, or NDVI, a measure of vegetation growth; Tucker *et al.* 1979) and other variables, such as topography or climate (e.g. Osborne *et al.* 2001). As with all distribution modelling, the accuracy of these maps must be verified, ideally using a subset of data not used in their development and, if possible, by further field surveys. Once verified, however, these maps can be invaluable to conservation. They permit ranges and population sizes to be estimated and potentially new, previously undiscovered populations to be found, even of globally threatened species such as Rudd's Lark *Heteromirafra ruddi* (Vulnerable) in South Africa (e.g. Maphisa *et al.* 2008). In the case of the Critically Endangered congeneric Liben Lark *H. sidamoensis*, these approaches highlighted the plight of the species. Models indicated that there were no other areas of habitat similar to those in the species' tiny range, other than a patch some 700 km distant close to the postulated range of the Critically Endangered congeneric and largely unknown Archer's Lark *H. archeri* (Donald *et al.* 2010).

Satellite image data have also proved to be useful in studies of species richness and diversity, as both correlate with spatial and temporal variation in the NDVI (e.g. Nøhr & Jørgensen 1997, Hurlbert & Haskell 2003, Bonn *et al.* 2004). Diversity increases with increasing spatial variation in land cover, and more productive areas (with higher NDVI) are often capable of supporting more species. The strength and ubiquity of these relationships suggests they could be applied to the prediction of species richness in under-studied areas. While this could enable areas of potential conservation concern to be identified (e.g. Johnston *et al.* 1998), areas of high species richness may not overlap with those of recognised conservation importance (Orme *et al.* 2005), meaning more research may yet be needed on the topic, but the possibility is there.

Monitoring land cover

Monitoring is essential for effective conservation, permitting problems to be identified, solutions developed and resources targeted. Bird monitoring in Africa is improving, and common initiatives are also in development in several countries. However, many sites of conservation importance, including many protected areas and BirdLife International's Important Bird Areas (IBAs) still do not benefit from any sort of systematic biodiversity monitoring. Satellite image data could help fill this gap (e.g. Turner *et al.* 2003, Buchanan *et al.* 2009a), by informing conservationists about the distribution of land cover (habitat) and how it is being altered. The most prevalent threats to the African IBA network are land-cover changes, many of which may be tracked using satellite images (Buchanan *et al.* 2009b), suggesting that remote sensing could play an important role in monitoring the integrity of the continent's most important sites for nature conservation. Satellite-based monitoring can cover extensive areas across multiple time periods through the availability of historical images (back to the 1970s in some cases; Fig. 1). To date, it is mostly forest loss that has been monitored using this method (e.g. Achard *et al.* 2002), but it is possible to track changes in other habitats (see, e.g., Brink & Eva 2009). Indeed, a collaborative project between BirdLife, the Royal Society for the Protection of Birds (BirdLife Partner in the UK) and global experts in the Global Environment Monitoring team at the European Commission's Joint Research Centre in Italy is piloting satellite image-based monitoring of all habitats in African IBAs using higher resolution images (Buchanan *et al.* 2009c). The development of new methods and increasing image availability will, it is hoped, see remote sensing routinely used to track land-cover change across the continent in conjunction with more traditional field-based monitoring.

Slightly lower resolution satellite data are now available in near real-time (e.g. SPOT-Vegetation, MODIS), making almost simultaneous monitoring a possibility. Wallin *et al.* (1992) suggested that such monitoring could be used to identify areas that were at risk from Red-billed Quelea *Quelea quelea*. While this was never delivered, experts are now in a position to develop near real-time monitoring systems designed primarily for the use of conservationists. A system for tracking fires is already available (Justice *et al.* 2002; Fig. 3), but other potential applications include systems that monitor the extent of waterbodies in West Africa (Haas *et al.* 2009). Further developments are underway and these should, in the next few years, deliver systems than can detect rapid changes, as well as long-term modification, including degradation, of vegetation across the continent, based on real-time data from the entire continent (if the land is not obscured by cloud). The potential value of such information to conservationists could be enormous.

Next steps

The technology is available now to improve our knowledge of bird distributions, track historical changes in land cover and develop a system to alert conservationists when land cover undergoes dramatic change. The use of these technologies will increase further in studies of African birds as data become more readily accessible to conservation organisations (e.g. Group on Earth Observation 2007, US Geological Survey 2008), as the types of data and number of sensors collecting the data increase, and as computing power and data storage capacity makes image processing faster and easier. Capacity development and increased resources are needed though to make full use of these capabilities. While international structures (e.g. Scholes *et al.* 2008) could make a substantial contribution to biodiversity conservation, smaller scale initiatives are needed to ensure that conservation in Africa benefits.

Remote sensing could make a great contribution to bird conservation in Africa. However, it must not be considered a panacea (not least because cloud cover can be a serious problem), and will never replace the need for field data. These are needed for processing or interpreting images, and without them the accuracy, and hence value, of remote sensing outputs cannot be assessed. Everyone can help, especially birders in Africa. Sharing of georeferenced photographs of birds and habitats (for example, through Google Earth) could provide a very useful archive of data for validating land-cover mapping. Birdwatchers also increasingly carry hand-held GPS units in the field; with a little extra effort, these could be used to record the precise locations of scarce or rare birds in the field. Online databases exist to collect such information (e.g. www.worldbirds.org), which could help develop and validate distribution models.

Acknowledgements

We thank Lincoln Fishpool, Roger Safford and Ron Demey for comments on an earlier version of this manuscript.

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Received 4 November 2009; revision accepted 16 November 2010.